

# Strategic Buffer Layer R & D for YBCO Coated Conductors

M. Parans Paranthaman, T. Aytug, A. Goyal, S. Kang, K. Leonard, H. Hsu, L. Heatherly, Jr., E.D. Specht, R. Feenstra, H.Y. Zhai, H.M. Christen, S. Sathyamurthy, C.E. Vallet, D.K. Christen, and D.M. Kroeger (ORNL)

P.N. Arendt, S.R. Foltyn, J.R. Groves, R.F. DePaula, L. Stan, and T.G. Holesinger (LANL)

R.E. Ericson (3M)

Research was sponsored by U.S. DOE, Office of Science, and Office of Energy Efficiency and Renewable Energy

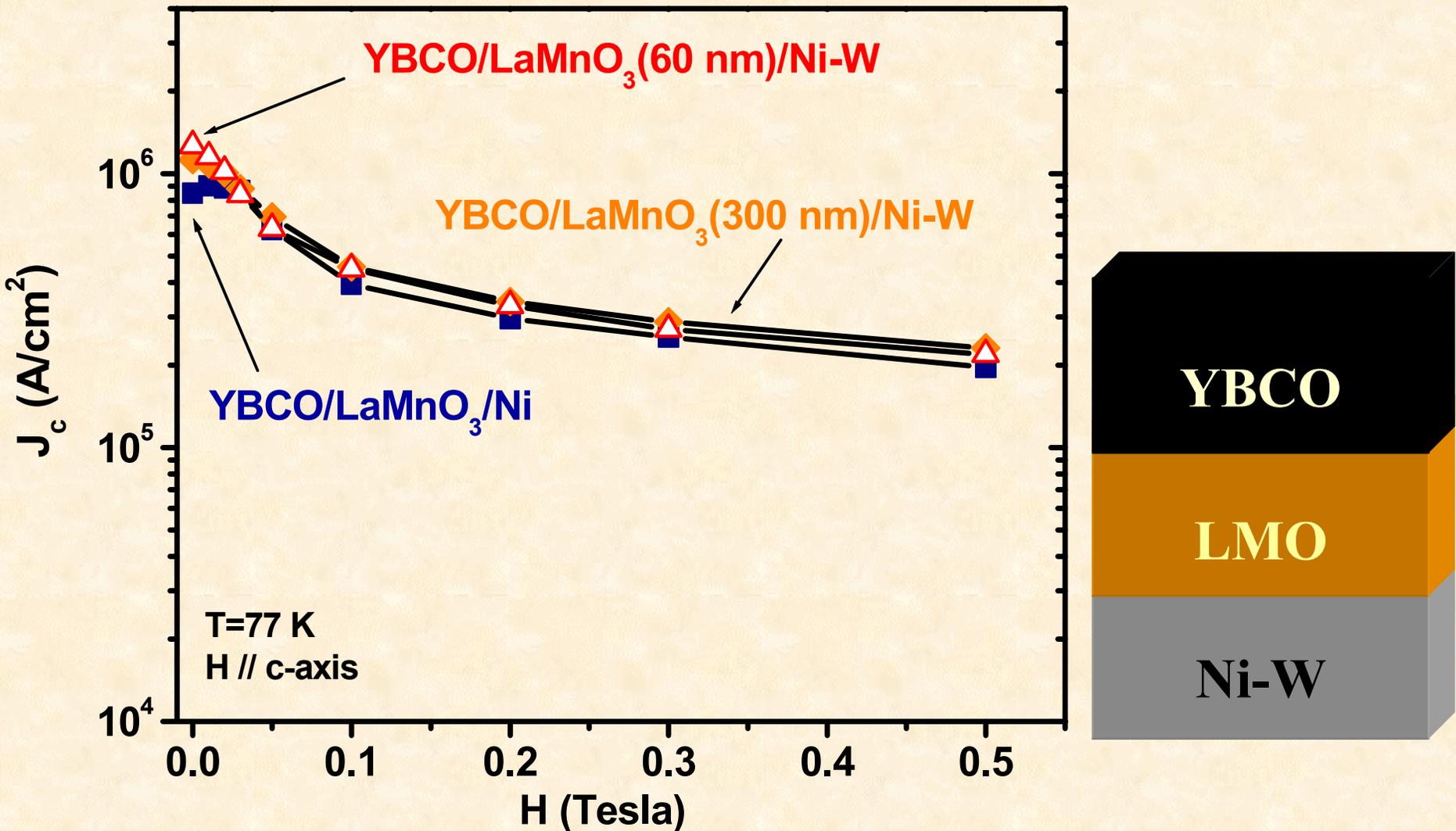
# Outline

- Selection of oxygen and nickel diffusion barrier layers
- $\text{LaMnO}_3$  based single buffer layers for YBCO/RABiTS
- Compatible-buffer-layer development for MgO-based tapes (*LANL IBAD MgO*)
- $\text{La}_2\text{Zr}_2\text{O}_7$  based solution buffer layers for YBCO/RABiTS
- Summary

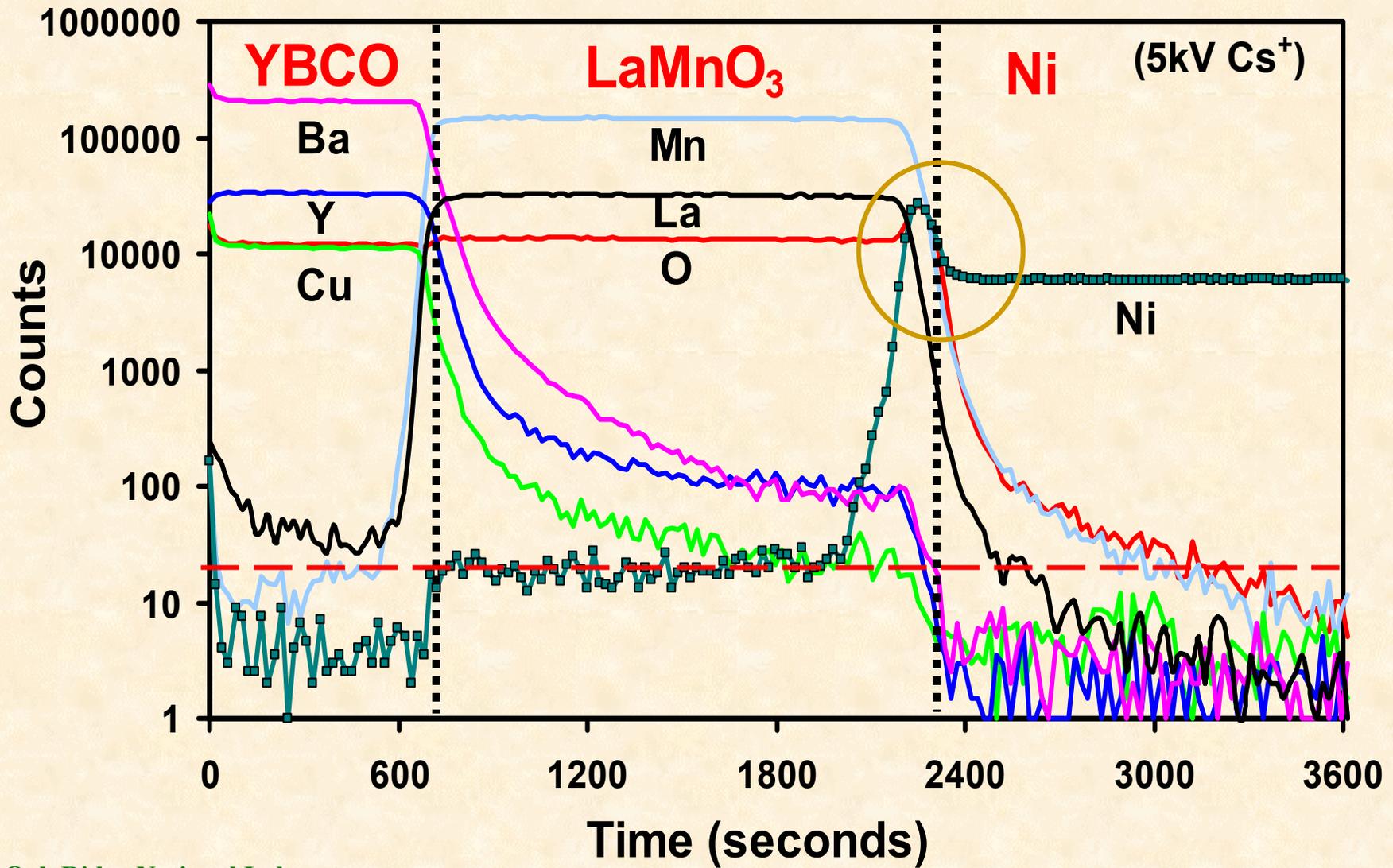
# Very low oxygen diffusion occurs in $MgO$ , which has a close-packed rock salt structure

Material	Crystal structure	Lattice parameter (pseudocubic) Å	% lattice mismatch vs. YBCO	% lattice mismatch vs. Ni	Oxygen diffusivity (cm <sup>2</sup> /sec) 700 °C	Oxygen diffusivity (cm <sup>2</sup> /sec) 800 °C
MgO	NaCl	4.210	9.67	17.74	$2 \times 10^{-23}$	$8 \times 10^{-22}$
SrRuO <sub>3</sub>	Perovskite	3.941	3.08	11.17		
SrTiO <sub>3</sub>	Perovskite	3.905	2.16	10.26	$6 \times 10^{-11}$	$2 \times 10^{-12}$
LaMnO <sub>3</sub>	Perovskite	3.880	1.60	9.70		
LaNiO <sub>3</sub>	Perovskite	3.859	0.98	9.07		
CeO <sub>2</sub>	Fluorite	3.826	0.12	8.22	$2 \times 10^{-9}$	$6 \times 10^{-9}$
Gd <sub>2</sub> O <sub>3</sub>	Type C	3.824	0.07	8.17	$2 \times 10^{-10}$	$7 \times 10^{-10}$
La <sub>2</sub> Zr <sub>2</sub> O <sub>7</sub>	Pyrochlore	3.814	-0.20	7.90		
LaAlO <sub>3</sub>	Perovskite	3.793	-0.75	7.35		
Y <sub>2</sub> O <sub>3</sub>	Type C	3.750	-1.89	6.22	$2 \times 10^{-10}$	$6 \times 10^{-10}$
YSZ	Fluorite	3.634	-5.03	3.07	$7 \times 10^{-9}$	$2 \times 10^{-8}$

# YBCO films grown on 60 nm thick LMO buffered Ni-W substrate using PLD carried a $J_c$ of over 1 MA/cm<sup>2</sup>

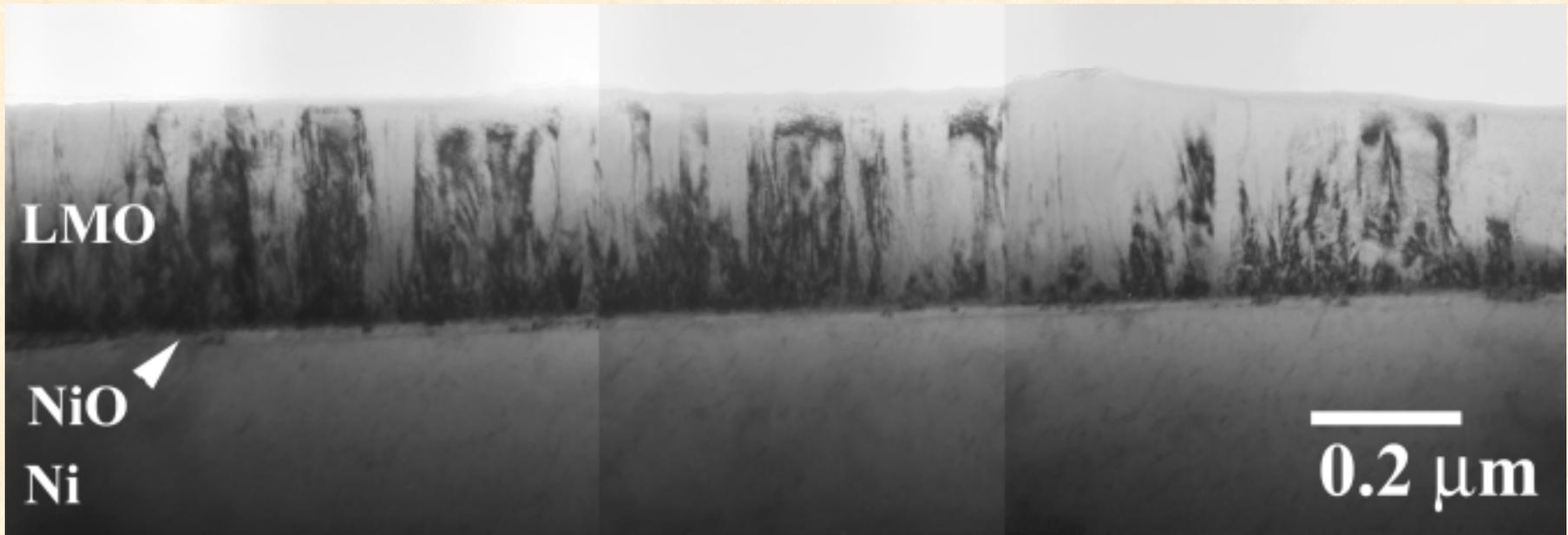


# SIMS depth profile analyses indicated no contamination of both YBCO (from LMO) and LMO (from Ni) layers

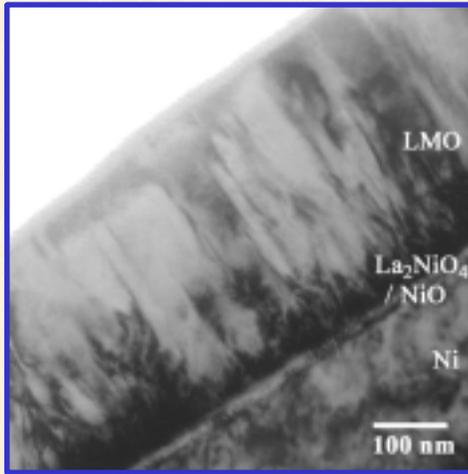


# LMO on Ni

Sputtered LMO has a columnar microstructure

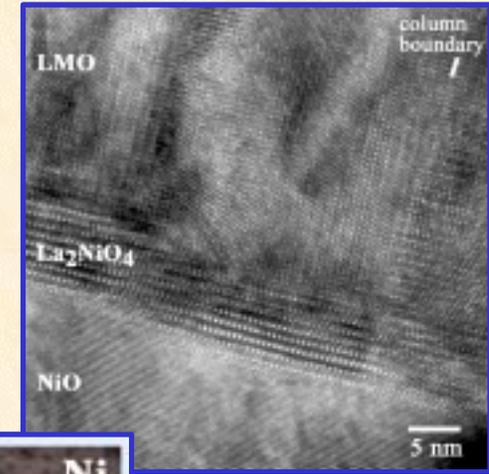


## Cross-section TEM image

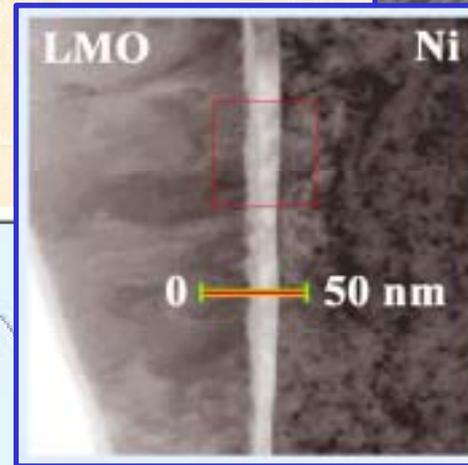
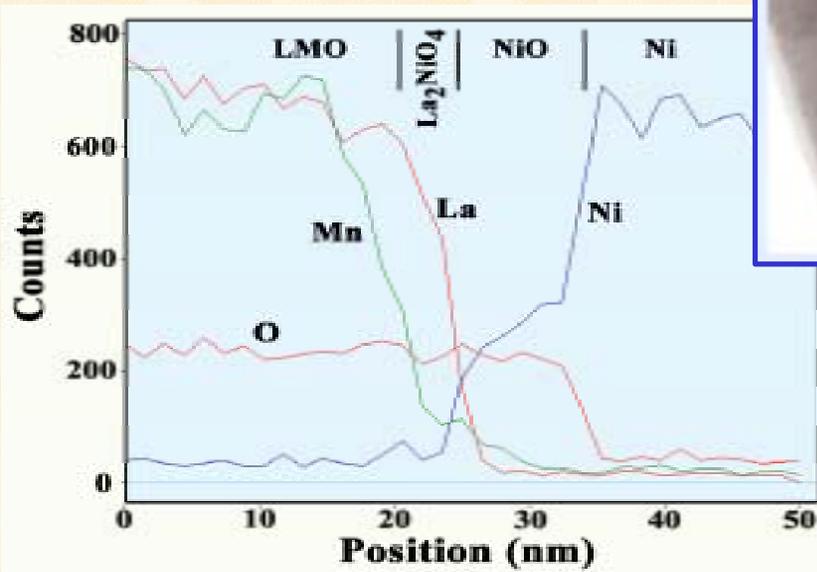


Sputtered LMO has columnar structure. A continuous thin layer of NiO & La<sub>2</sub>NiO<sub>4</sub> appears between LMO & Ni interface. We believe that La<sub>2</sub>NiO<sub>4</sub> facilitates the epitaxial growth of LMO on Ni[100].

## High resolution STEM image

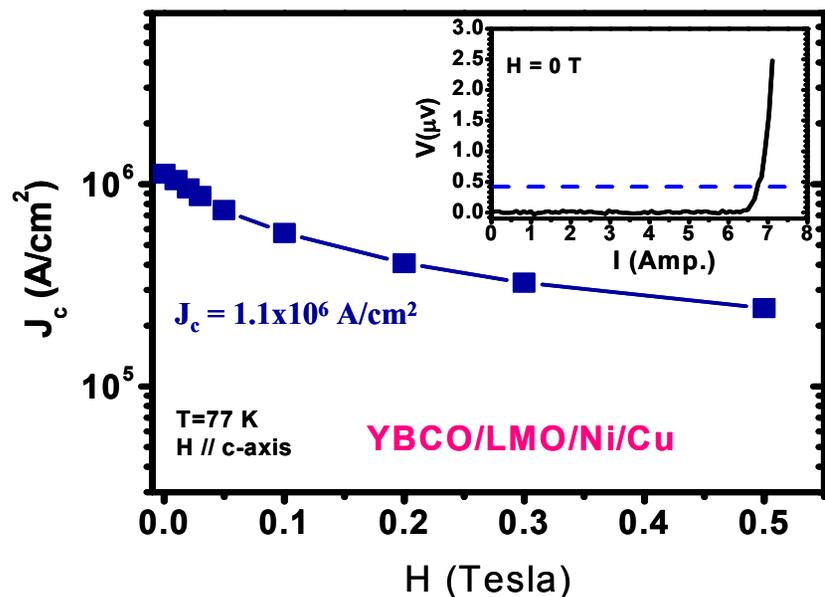


## Line scan profile at LMO/Ni interface

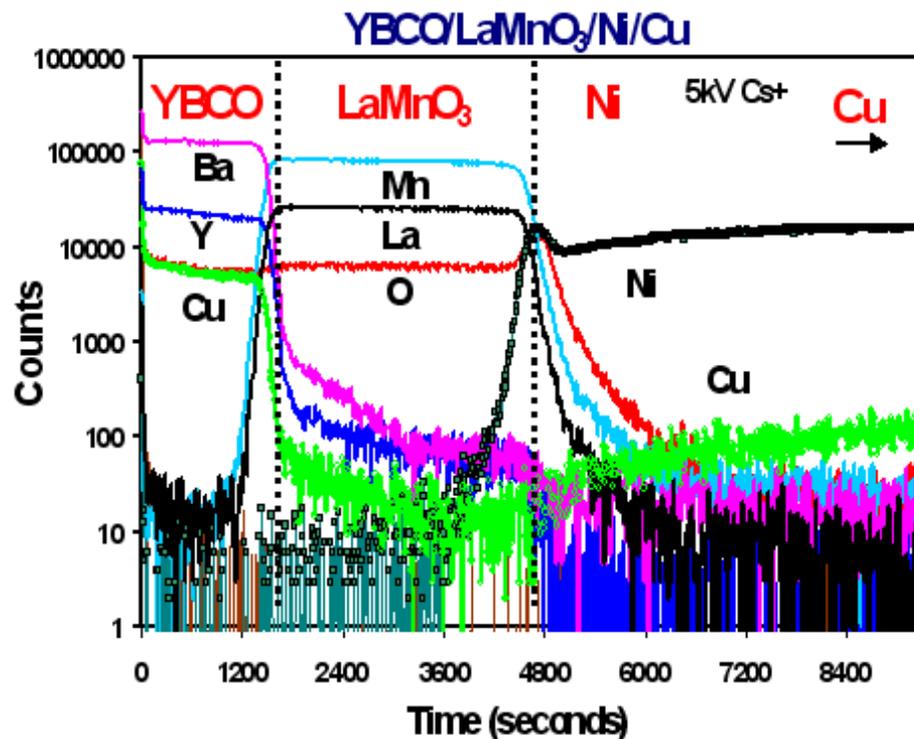


Line scan at LMO/Ni interface clearly shows formation of 5 nm & 10 nm thick La<sub>2</sub>NiO<sub>4</sub> & NiO, respectively.

# LaMnO<sub>3</sub> blocks Ni as well as Cu diffusion into the YBCO layer



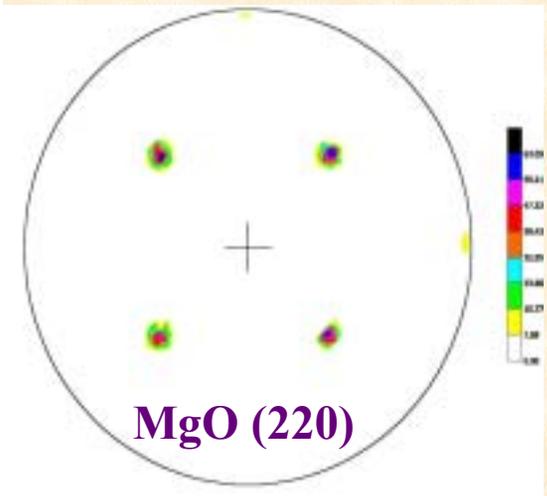
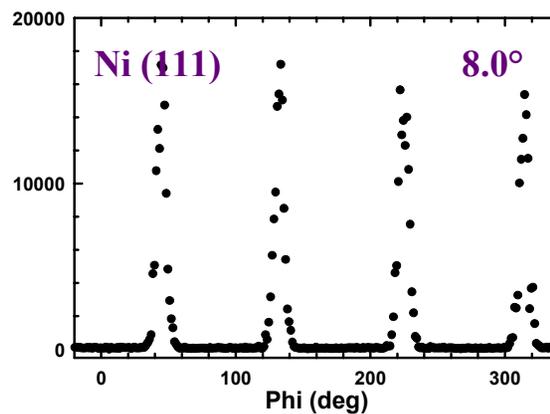
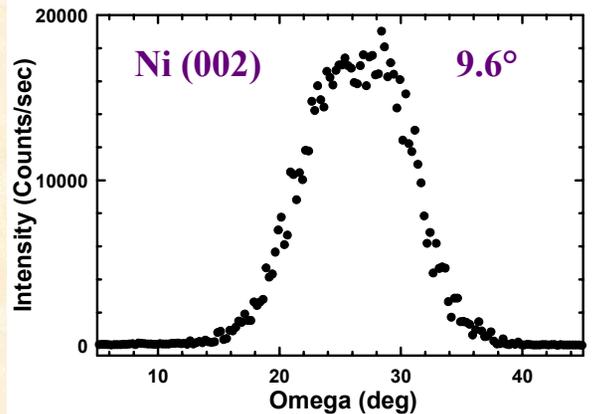
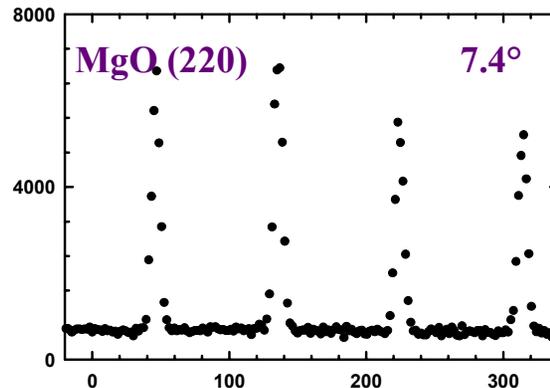
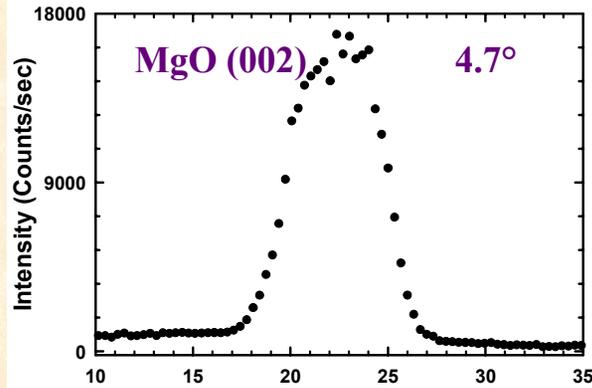
$H$  versus  $J_c$ : YBCO (200 nm) films on LMO/Ni buffered Cu substrates yield high- $J_c = 1.1$  MA/cm<sup>2</sup>.



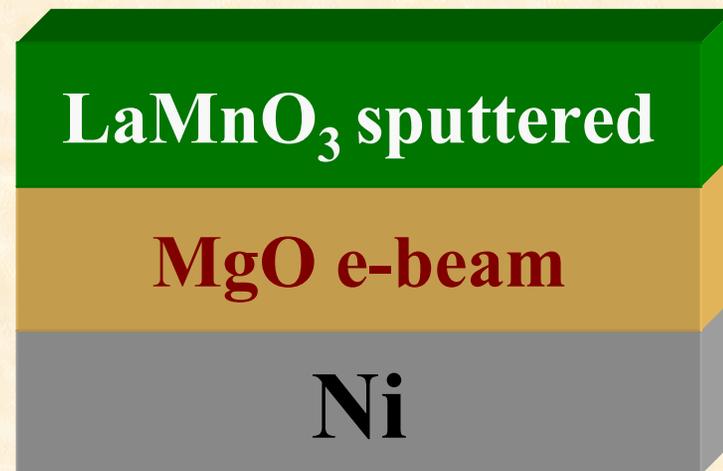
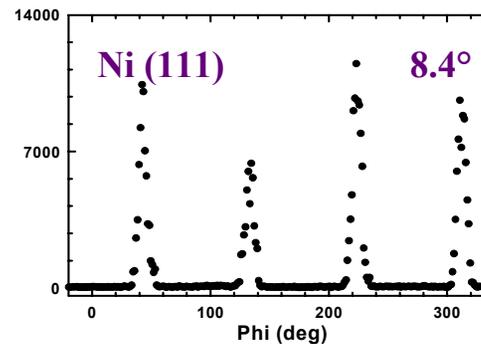
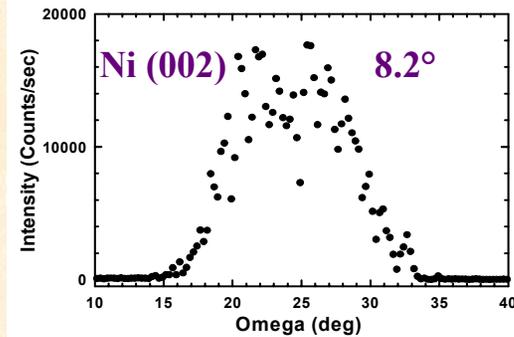
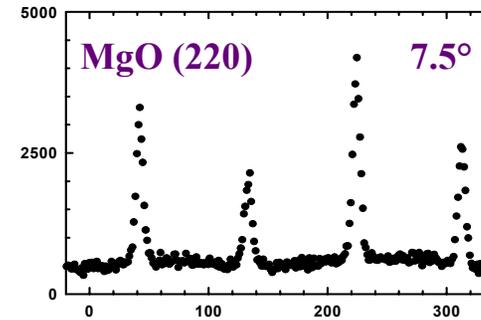
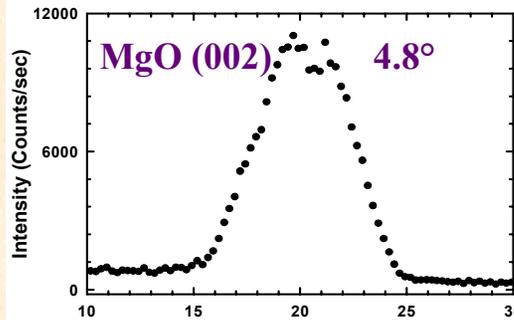
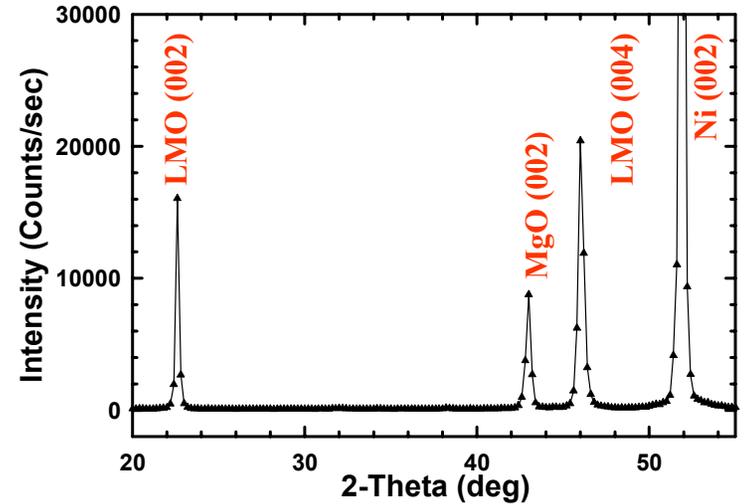
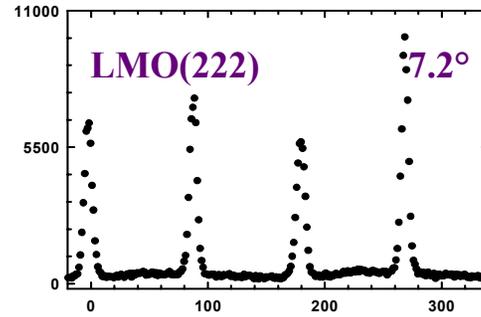
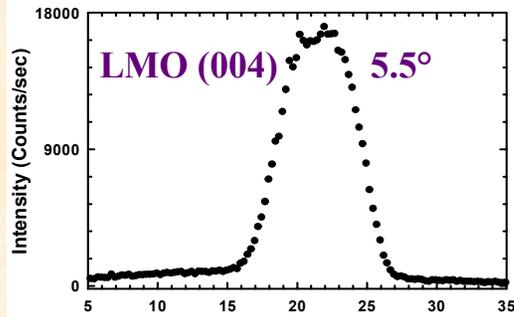
SIMS Depth Profile Analysis

T. Aytug et al., J Mater Res (2003) (in press)

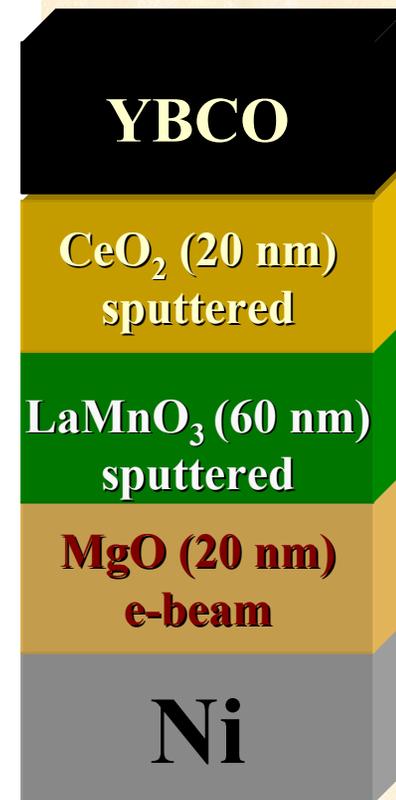
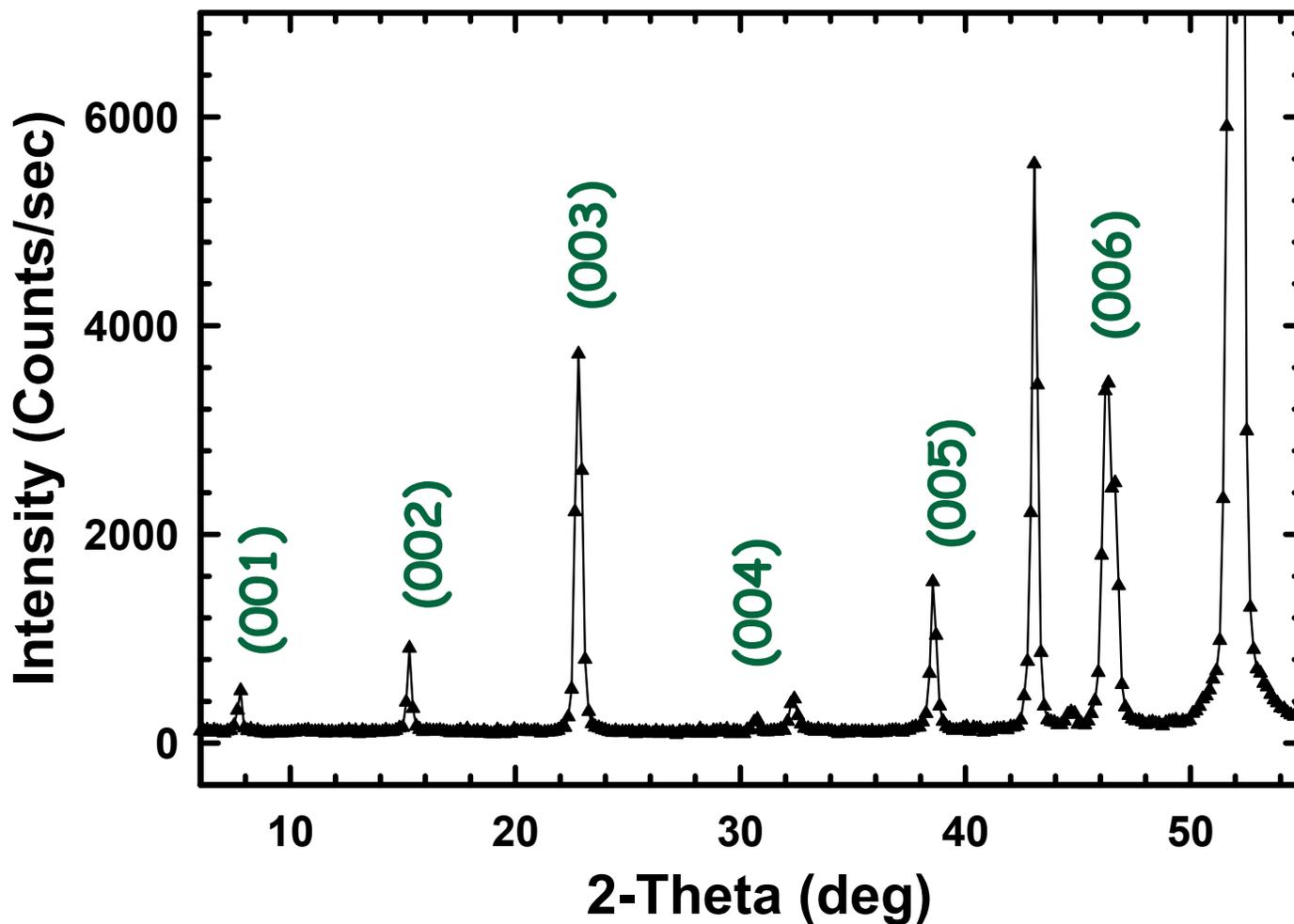
# Highly aligned MgO buffers were grown directly on textured Ni substrates using e-beam evaporation



# Highly aligned $\text{LaMnO}_3$ buffers were grown on MgO-buffered Ni substrates

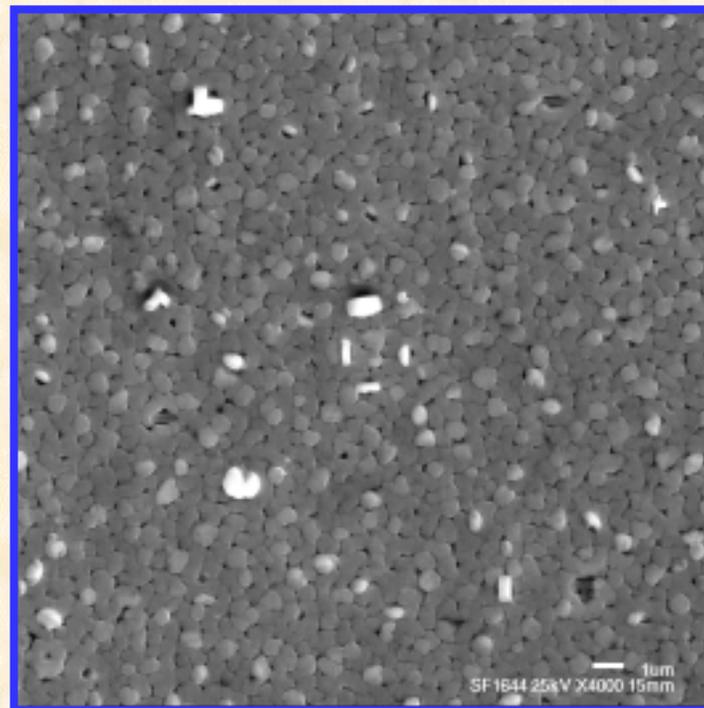
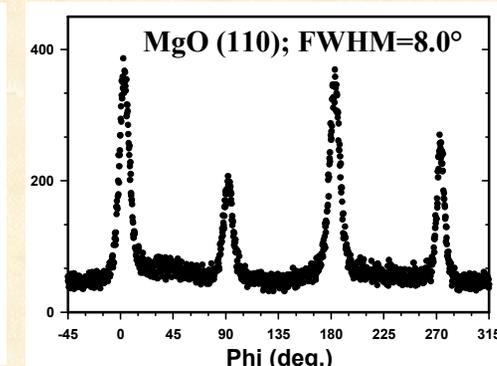
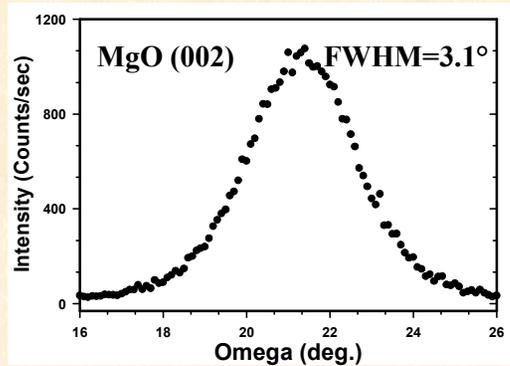
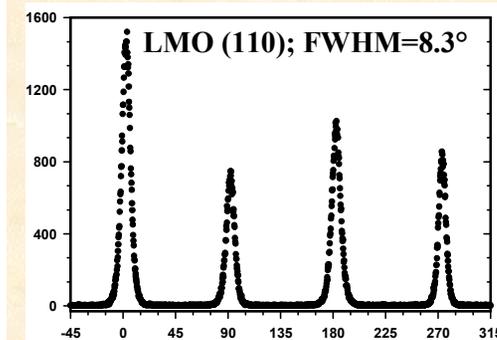
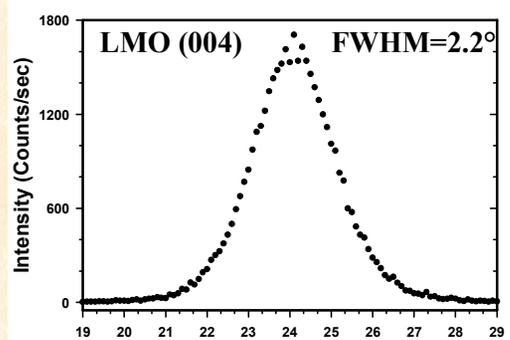
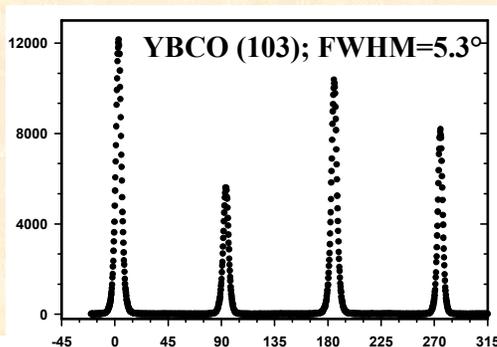
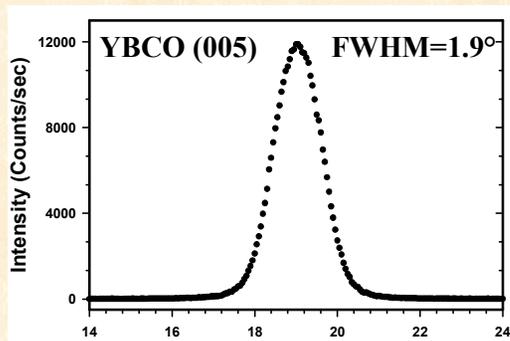


# Optimization of the growth of YBCO films on LMO-buffered MgO/Ni substrates with/without CeO<sub>2</sub> cap layer is in progress



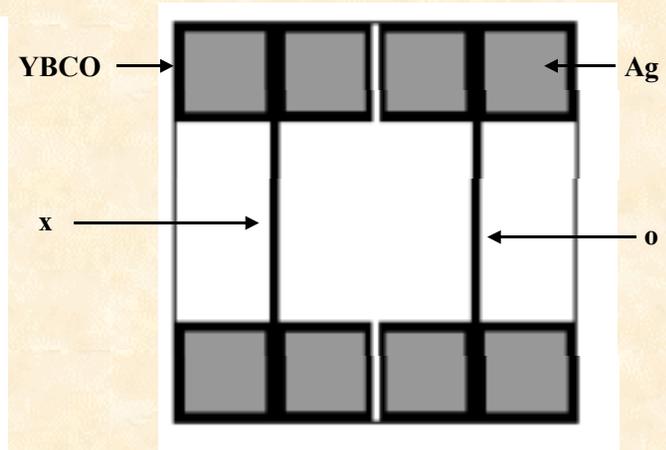
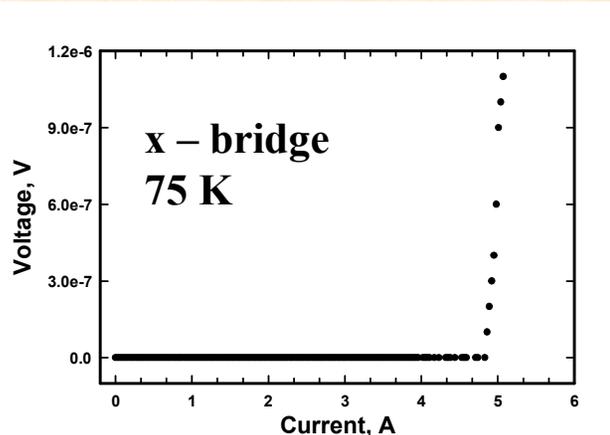
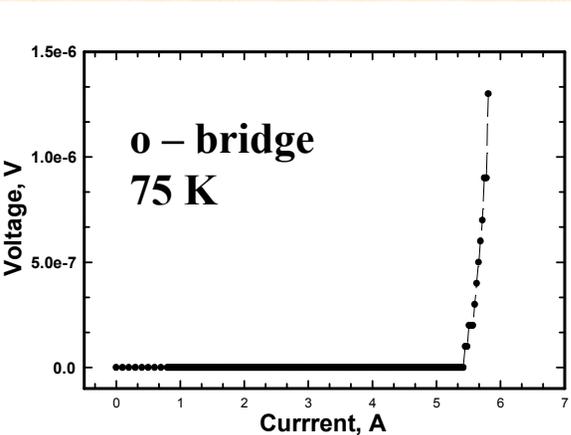
*LaMnO<sub>3</sub> Buffers for non-RABiTS based  
YBCO Coated Conductors*

# Demonstrated the growth of high $I_c$ YBCO films on LMO buffered IBAD-MgO substrates at LANL



Thick YBCO films with dense microstructures were produced

# High $I_c$ of over 230 A/cm was obtained at 75 K

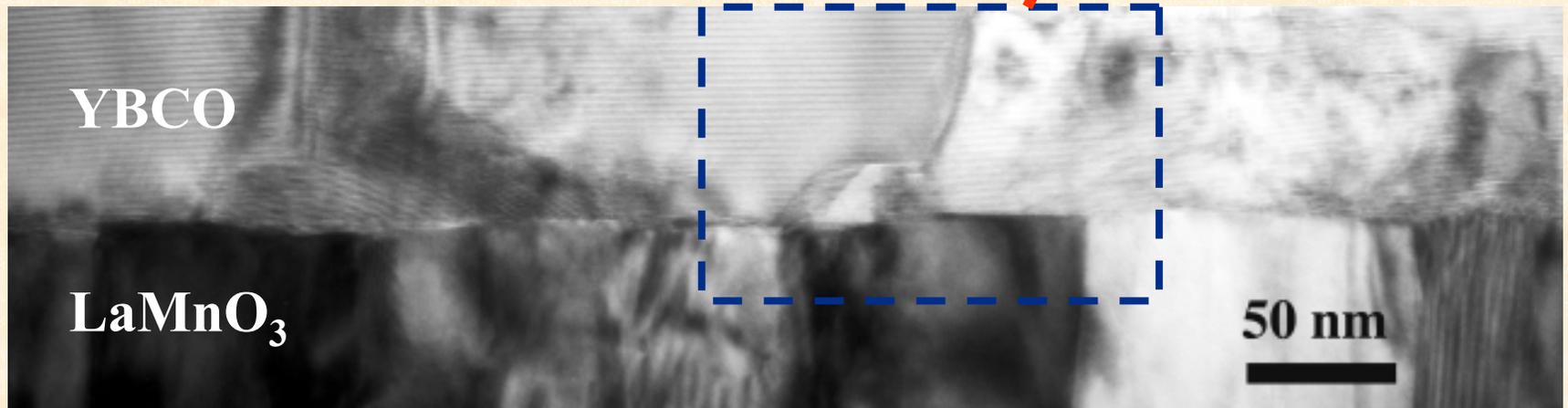
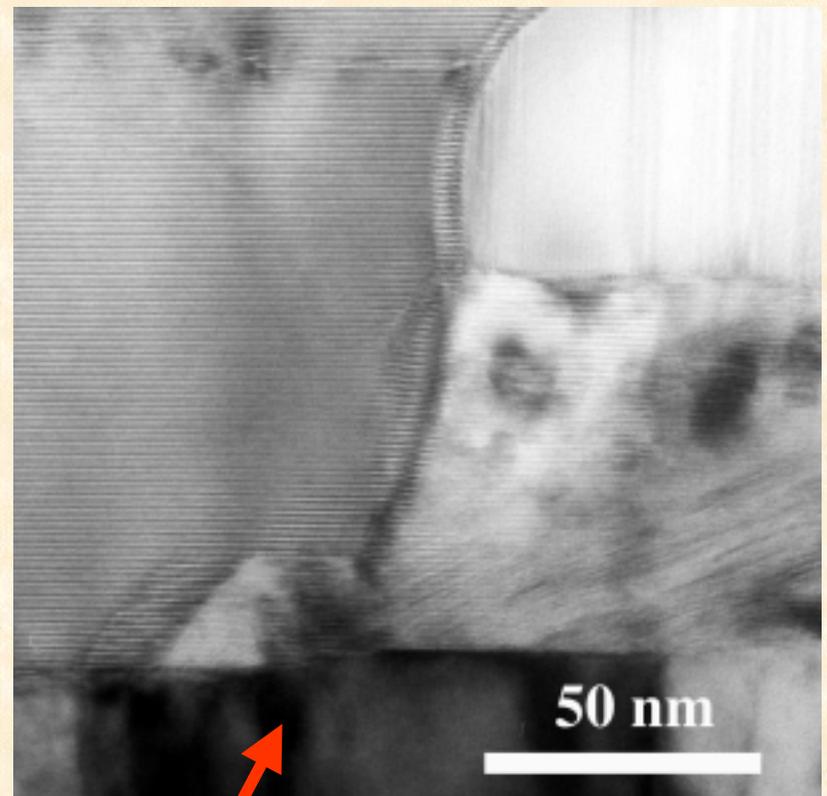


	width	length	thickness	$I_c$	$J_c$
x- bridge	235 $\mu\text{m}$	5 mm	1.65 $\mu\text{m}$	4.96 A	1.3 MA/cm <sup>2</sup>
o- bridge	225 $\mu\text{m}$	5 mm	1.65 $\mu\text{m}$	5.66 A	1.5 MA/cm <sup>2</sup>

## Architecture: YBCO/LMO/IBAD-MgO/Ni-alloy

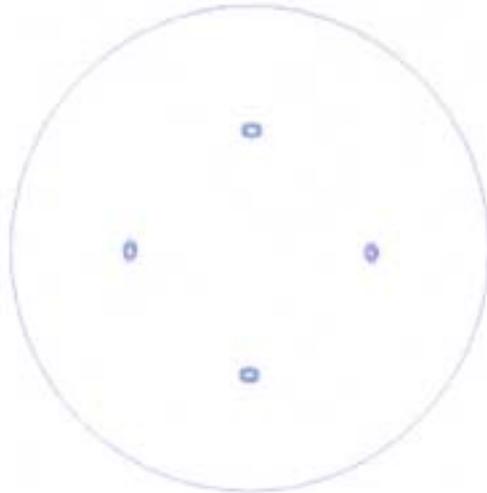
→ Clean interface between  
the YBCO and LaMnO<sub>3</sub> buffer  
layer

YBCO/LaMnO<sub>3</sub>/IBAD-MgO/Ni-alloy  
PLD YBCO  
Sputtered LaMnO<sub>3</sub>



# YBCO/CeO<sub>2</sub>/LMO/MgO-IBAD

YBCO  
(103)/(013)  
pole

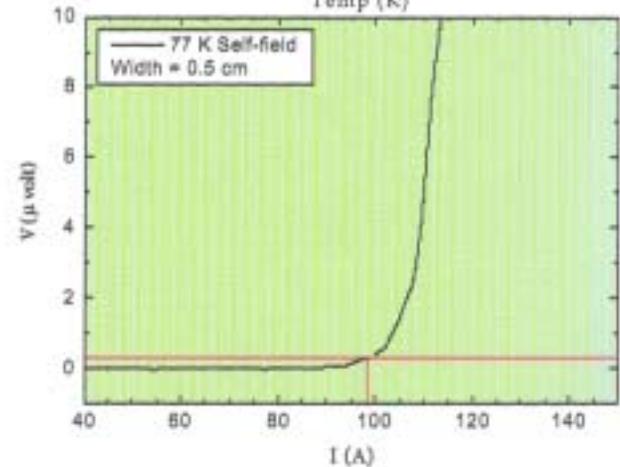
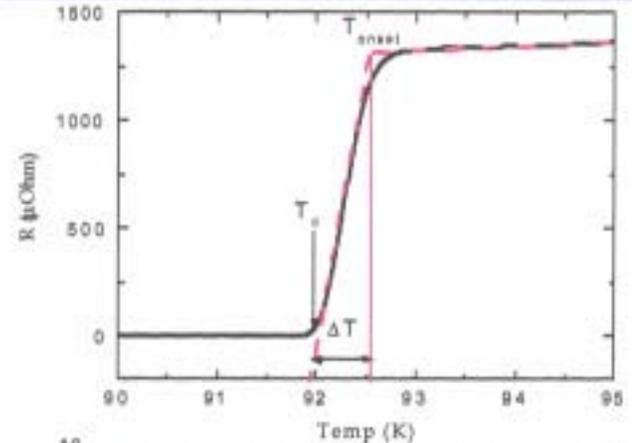


Texture evolution

YBCO:  $\Delta\phi_{103} = 2.5^\circ$ ;  $\Delta\kappa_{005} = 2.5^\circ$

CeO<sub>2</sub>:  $\Delta\phi_{111} = 5.5^\circ$ ;  $\Delta\kappa_{002} = 1.8^\circ$

LMO:  $\Delta\phi_{110} = 6.5^\circ$ ;  $\Delta\kappa_{004} = 2^\circ$



$J_c(77K) = 2.2 \text{ MA/cm}^2$ ,  $I_c = 194 \text{ A/cm-w}$ ,  $T_c = 92 \text{ K}$ ,  $\Delta T_c = 0.5 \text{ K}$



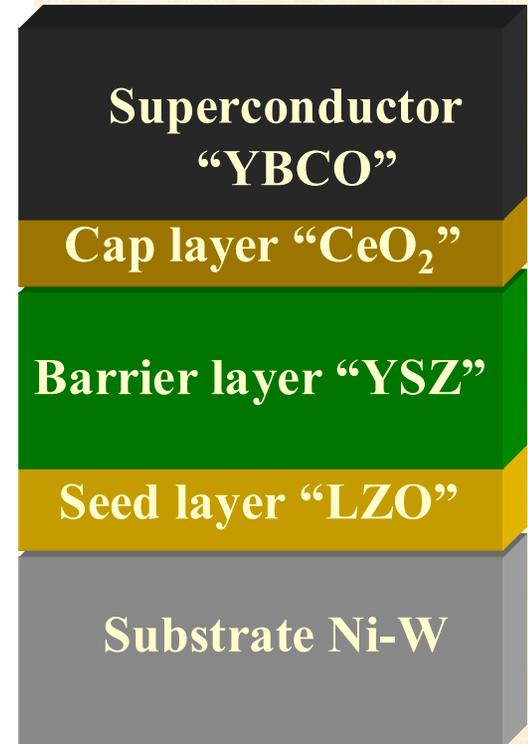
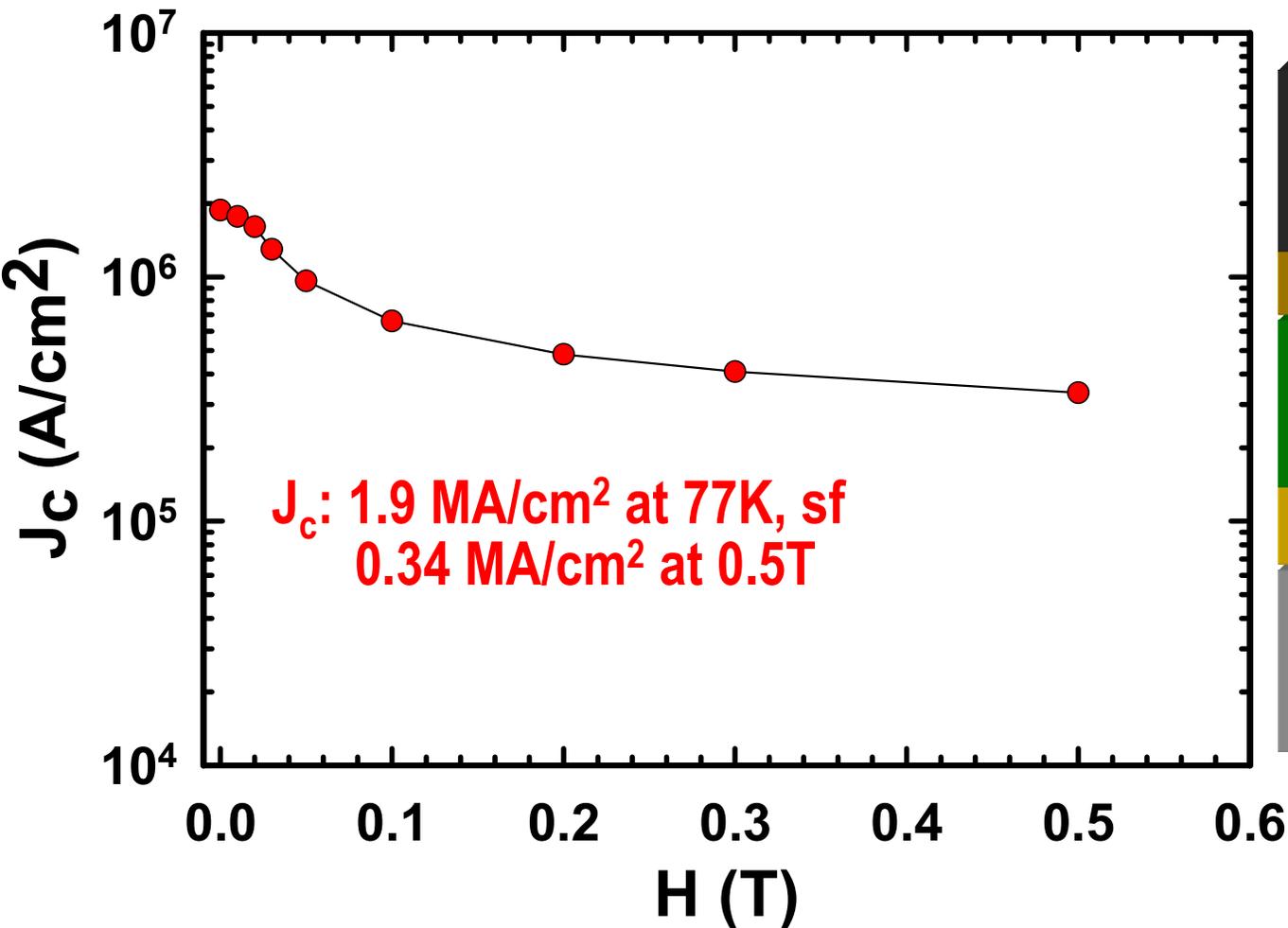
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Xiaoping Li (AMSC)

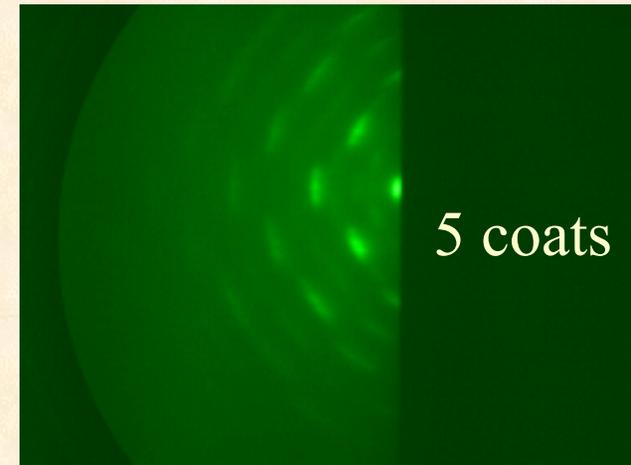
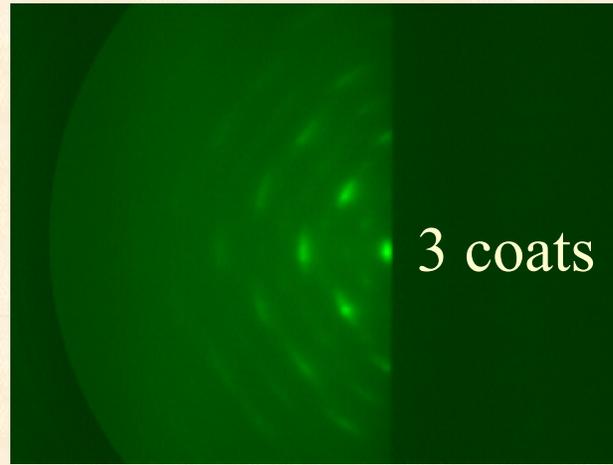
# Solution based $\text{La}_2\text{Zr}_2\text{O}_7$ buffer layers for YBCO/RABiTS

# LZO seeds on Ni-3%W substrates yielded high current density YBCO films grown by PLD



The performance of solution LZO seed layers approach that of e-beam Y<sub>2</sub>O<sub>3</sub> seed layers

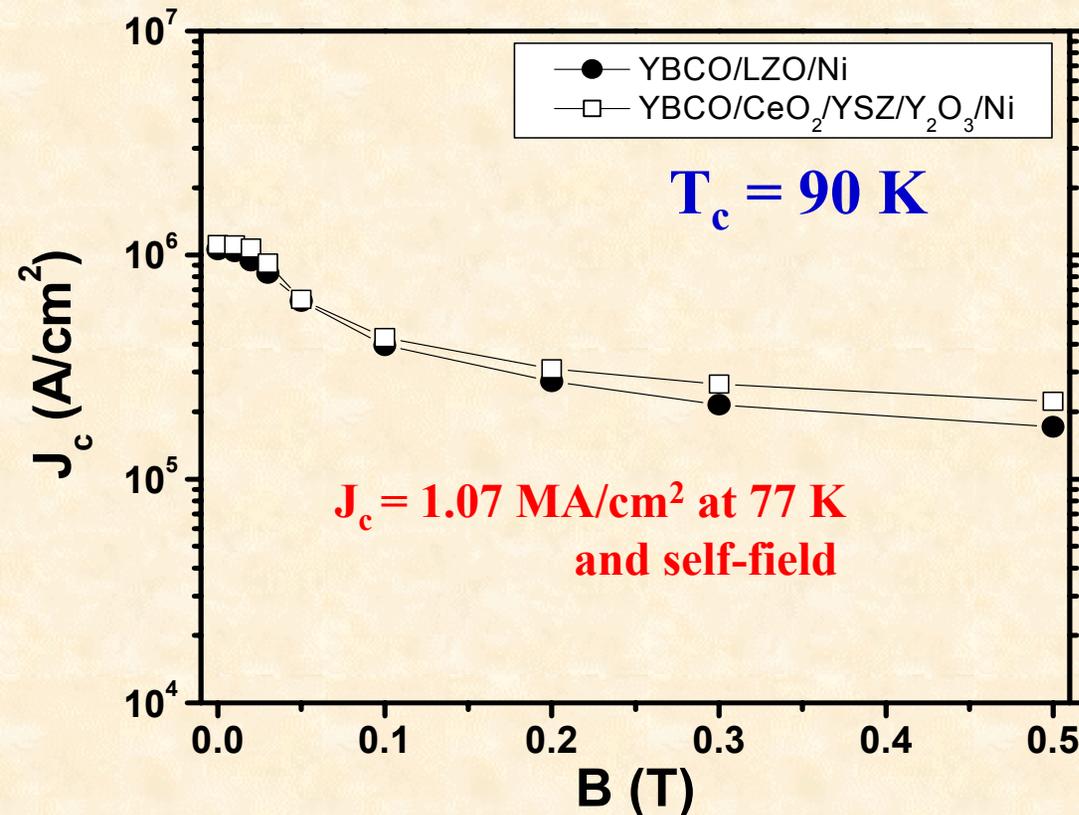
## Surface studies of LZO multiple coats



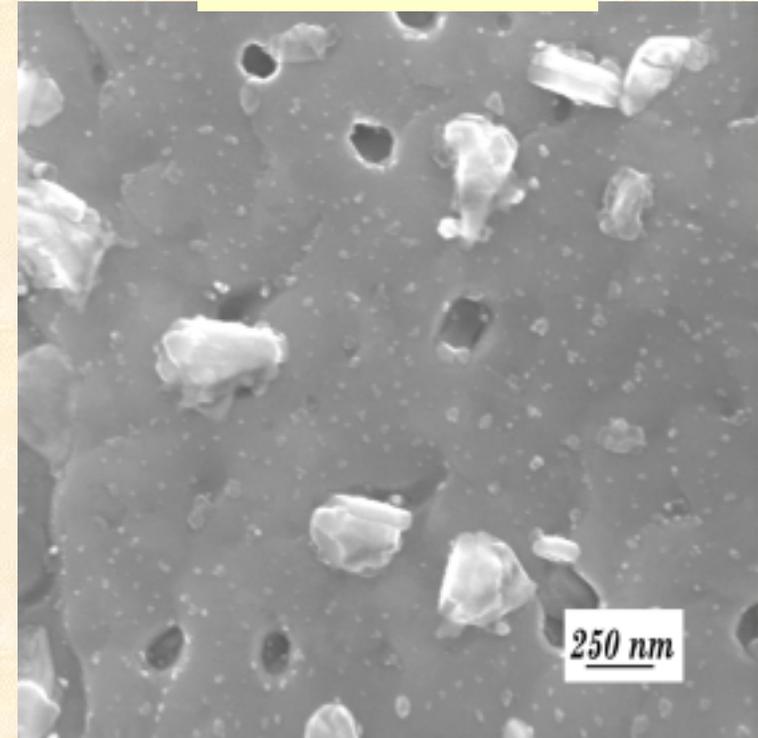
Solution processing of LZO very different from that of  $\text{Gd}_2\text{O}_3$

No evidence of polycrystalline or amorphous material on film surface

**YBCO films (0.2  $\mu\text{m}$ ) with a  $J_c$  of over 1 MA/cm<sup>2</sup> have been grown on all solution 60 nm thick LZO buffered Ni substrates using PLD**

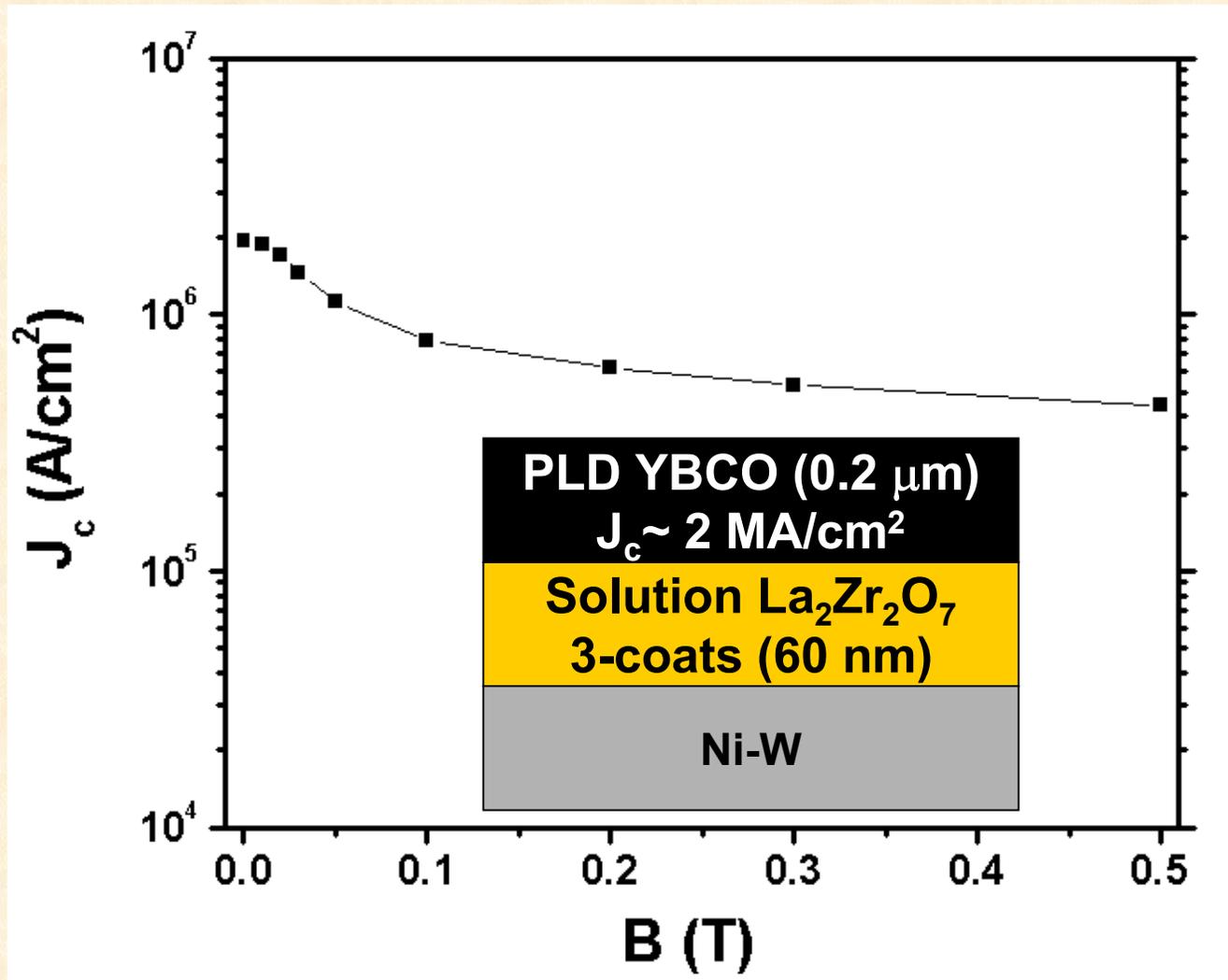


YBCO/LZO/Ni



**The performance of single solution buffer layers approach that of our standard three-layer architectures**

# All Solution-grown Single Buffer Layer Yielded 2 MA/cm<sup>2</sup> YBCO Conductor on Ni-W substrates



# Summary

- $\text{LaMnO}_3$  layer has been identified as an excellent Ni and Cu diffusion barrier layer
- Developed a new alternative MgO based RABiTS architecture:  $\text{CeO}_2/\text{LMO}/\text{MgO}/\text{Ni-alloy}$
- LMO is highly compatible with IBAD-MgO buffers; High  $I_c$  of  $> 230 \text{ A/cm}$  were produced
- LZO has also been identified as an excellent Ni diffusion barrier layer
- YBCO films with a  $J_c$  of  $2 \text{ MA/cm}^2$  were produced on all solution LZO buffered Ni-W substrates